ENGINEERING EVOLUTION PART IX

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BRAKES
A GRIPPING SUBJECT

BRAKING SYSTEMS probably have absorbed more expert and amateur criticism in the last 15 years than has any other area of design on the American car. Perhaps a brief look at how these American passenger car brake systems evolved for the last 50 years will help throw some reveal ing light on the subject.

Actually, the earliest cars had their brake on the driveshaft, operated either by a foot pedal or hand lever. Early road speeds of 10 mph really didn't require much more. From there it was a simple step to brakes on the rear wheels only. Generally, the driveshaft brake was retained, operated by foot, for normal everyday braking—with the rear-wheel brakes operated by a hand lever for emergency stopping. When normal road speeds rose above 20 mph the engineers merely switched the layout by hooking up the rear brakes for foot operation, with hand operation of the driveshaft brake for emergency. Front-wheel brakes weren't in the picture then; they were used on a few European cars before 1910, but didn't catch on over here until much later.

To get some idea of the performance of those early rear-wheel brake systems, we have some results of tests run on a number of contemporary cars by the Automobile Club of America in New York in 1902. Stopping distances were averaged by the formula $V^2/6.7$. This would be equivalent to a stopping distance of 60 ft. from 20 mph. A modern car can stop in 15 ft. or so from this speed. In fact, even by 1915 rear-wheel brakes had been improved to the point where they could stop in 40 ft. or so from 20 mph. But imagine this kind of brake performance in modern traffic!

Early brakes were generally of the external-contracting type. A long brake band wrapped around the outside of the drum, and levers and cams to squeeze the ends of the band together applied the brake. It was the simplest possible layout from a mechanical standpoint. The big disadvantage was that there was no self-energizing action to multiply the pedal force into giving more braking torque on the drum. This external brake also was exposed to mud and water which not only hurt its performance in wet weather, but also caused fast wear of the friction material. This latter was generally an asbestos-base material, with reinforcement of cotton yarn or brass wire to give a fabric that could be woven into the strip. (The short asbestos fibers were impossible to weave alone.) This made a fairly tough friction material, but it was too hard to give the high friction coefficients that are considered necessary today.

This external rear-wheel brake with woven asbestos band remained in vogue on American cars for many years—up through World War I. In fact, there were many similar systems on the market even as late as 1925. Interest in 4-wheel brakes started in the early 1920s. Fred Duesenberg is generally credited with the first serious attempt at an improved braking system on his new Model A luxury car of 1921. He used front and rear internal brakes and even went a step further by applying them hydraulically, instead of through the usual levers, shafts and cables.

Admittedly, Duesenberg's hydraulic system was crude. It used a mixture of water and alcohol for the fluid which was fed to the wheel cylinders entirely through metal pipes and drilled holes. No flexible hoses. The fluid was

pumped to the swiveling front brakes through holes drilled in the knuckle forging and up through the kingpin. Leakage was a serious problem but Duesenberg's new 4-wheel hydraulic brakes gave better stopping with less pedal pressure than American motorists had ever seen before. The development is generally considered an important milestone for American cars.

Four-wheel hydraulic brakes were used on the newly-introduced Chrysler Six in 1924 and several other American makers went to 4-wheel mechanically-operated brakes about this time (Packard, Studebaker, etc.). Mechanical operation of front brakes was always a headache, though, because of the need to provide some sort of swiveling connection for the steering of the front wheels. All sorts of mechanisms were tried. But they all had friction and slop, unhealthy situations for any brake system. This was a big factor behind the surge to hydraulic brakes.

About 1927 there were vital developments in other areas of brake design, such as the move to self-energization. Up until then, cars had used either external-contracting band brakes or internal dual-shoe brakes with anchor pins at the bottom of both shoes. Neither of these types of brakes has any inherent self-energization. The driver had to put full effort on the brake pedal for every ounce of stopping force. But brake engineers were figuring how they could multiply pedal effort by different arrangements of their shoes and anchors.

The now-famous Bendix "duo-servo" brake was born at this time. This system had the bottom of the primary shoe connected to the bottom of the secondary shoe through a cross link, so that drum friction would try to pull the primary shoe down harder. This force would be transmitted across to the secondary shoe to push it harder against the drum also! Every pound of applying force against the tops of the shoes was multiplied three to five times in pressure against the drums. The earliest Bendix duo-servo brake installations, in 1930, were mechanically actuated but there was no comparison between pedal effort for these brakes and usual non-servo brakes of that day. The idea mushroomed in popularity and today Bendix brakes are used on all American cars. It seems to be the best way to achieve minimum pedal effort.

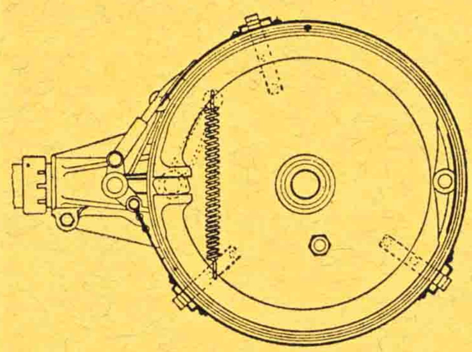
Another interesting, self-energizing brake developed in the late '20s, was the "Steeldraulic." In this system the brake lining went almost all the way around the inside of the drum, mounted on a flexible shoe. A toggle arrangement pressed both ends of the shoe against the drum, reacting on a single anchor pin. The brakes were applied mechanically through flexible cables that exerted a torque on the cams, rather than a push-pull action. Hence the name Steeldraulic. This brake even had even slightly more self-energization than the Bendix duo-servo! The wheels could be locked with only 125 lb. pedal pressure—something unheard-of in those days. By the same token, the brake was very sensitive to changes in lining friction. This has proved to be the Achille's Heel of all high-servo brakes. With the crude friction linings available in those days, brake pulling and grabbing was the problem which held back the high-servo brake.

In fact, it was this type of brake that pushed the lining suppliers to work harder on improved friction materials. Molded brake lining, introduced in 1924, was a vital step forward. Here the asbestos fibers were mixed with various organic binder materials and molded into a solid block of material under heat and pressure. These lining strips were then attached to the brake shoe by riveting, just like the earlier woven lining. Advantages: It was possible to make softer friction materials with higher friction coefficients without excessive wear rates. The molded linings were less affected by water, grit, or high working temperatures. Friction coefficients were more consistent and stable. All these qualities made molded linings highly desirable for the new high-servo brakes that were showing up in the late '20s. It is likely that these brakes would not have survived without the improved linings. Some of the early high-servo installations got a bad reputation for unstable braking when used with the old woven linings.

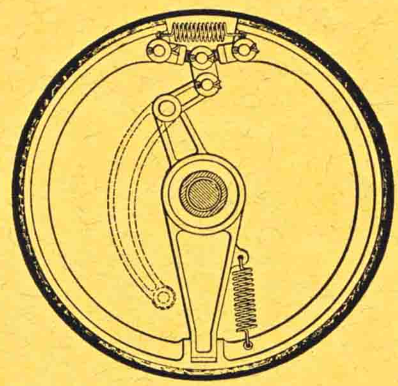
By the early 1930s most American cars had brakes on all four wheels. All were of the internal-expanding type, but about equally divided between mechanical and hydraulic actuation and between servo and non-servo layout. The modern brake layout hadn't jelled at that time although there were a number of vacuum power boosters in those days, mostly on the higher-priced cars. If we remember that a mechanical actuation linkage has considerable friction to overcome and combine this with the lack of self-energization on many cars of that day, we find a situation where it was next ►

Major Steps in Braking History

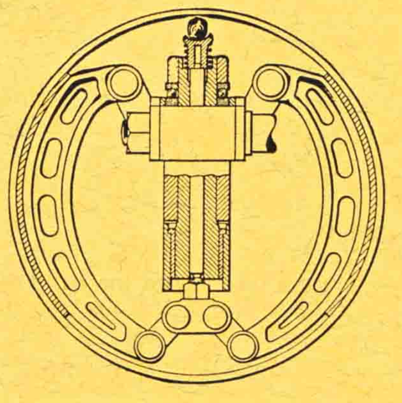
INTERNAL-external brake of 1910-15 era had long one-piece shoe on outside which bent when cam expanded its ends.



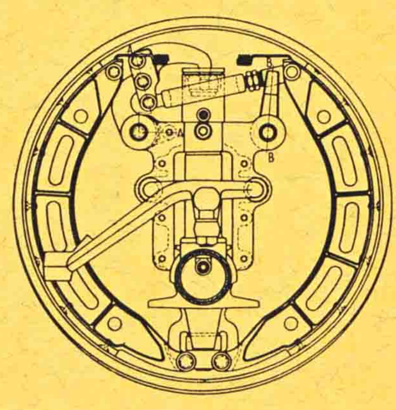
LEVER-type expanding brake of 1922 had flexible internal shoe which was spread to contact drum by lever linkage at top.

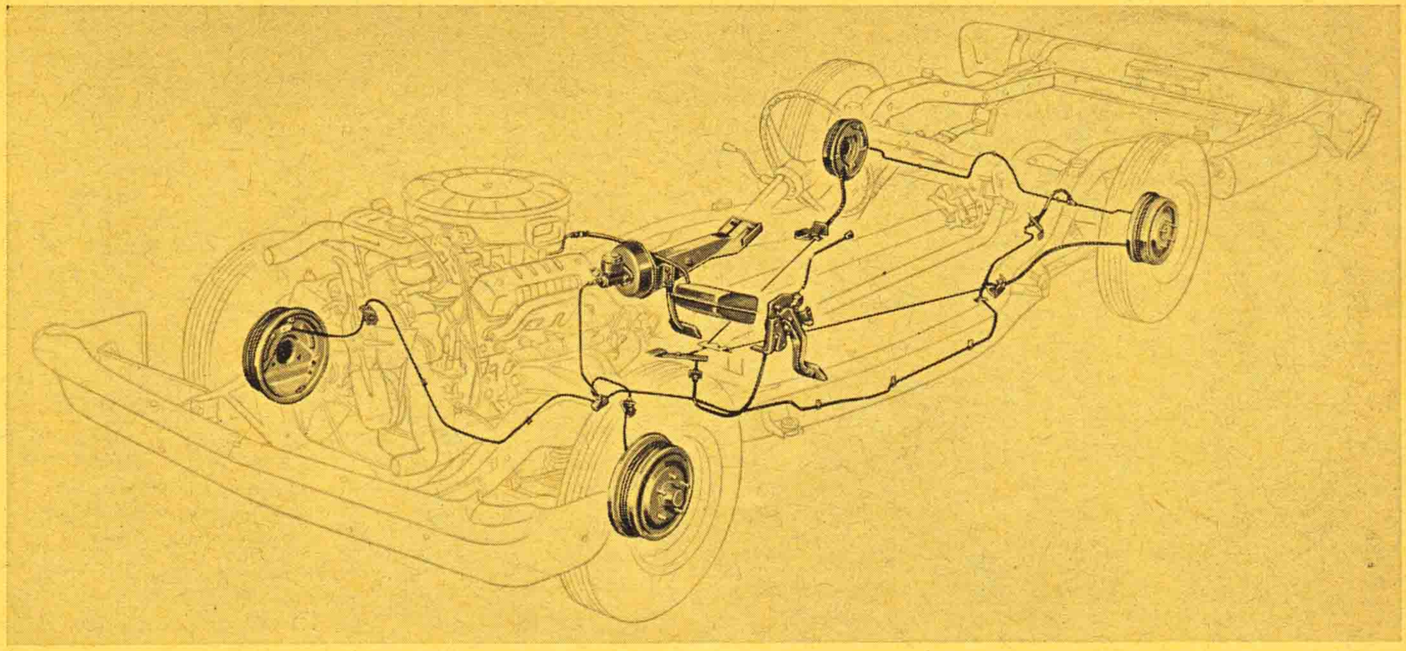


TWO-shoe expanding brake of '20s for front wheels pressed shoes straight out against drums; no self-energization.



MODEL A Duesenberg front brakes of 1921; first 4-wheel hydraulics on U.S. car. Wheel cylinder is vertical, in center.





THE MODERN 4-wheel hydraulic brake system has a vacuum-powered pedal assist on the master cylinder, individual lines running to each wheel where single cylinders operate a self-adjusting, self-energizing duo-servo two-shoe brake.

BRAKES

to impossible for even a strong man to lock the wheels on some of the bigger, heavier cars of the day. Vacuum assist was virtually a necessity. Then, as the carmakers moved toward servo brakes and hydraulic actuation, the vacuum boosters faded away.

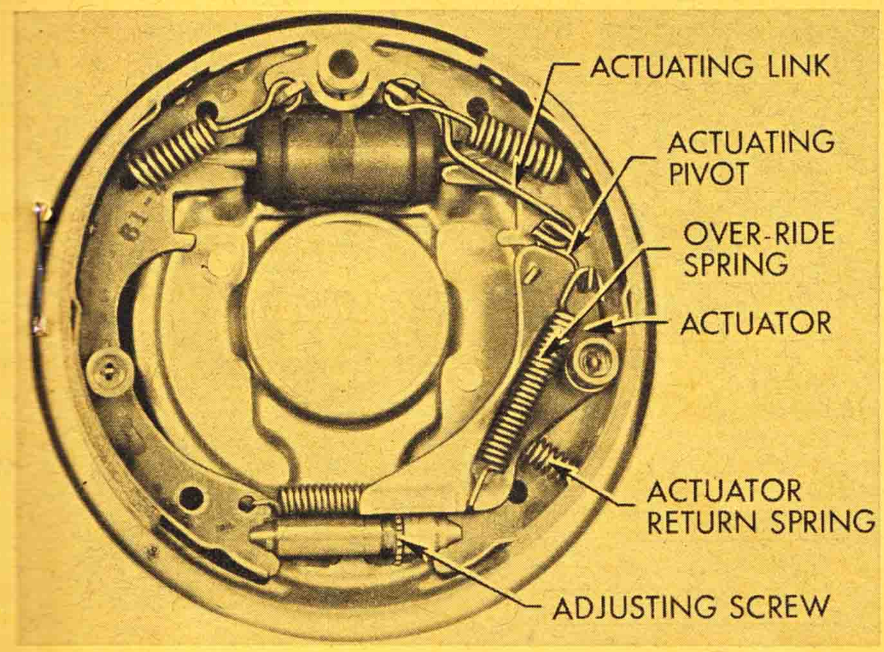
In 1940 Chrysler went to the 2-leading-shoe Lockheed brake. This had been popular for years in Europe. Here both shoes are made self-energizing by putting a hydraulic cylinder and anchor pin on each one, so drum friction will act to press both of them harder against the drum. This had double the self-energization of the conventional non-servo brake (single cylinder, two anchors) and about half that of the Bendix brake. Chrysler engineers felt this would be a good compromise between pedal effort and stability. Even in those days, with the lining materials available, duo-servo brakes were very prone to fade and instability under hard braking conditions—as in mountain driving or when pulling a trailer. Chrysler wanted to get away from some of this, even though it meant some increase in pedal effort and higher costs because two cylinders were required for each brake (though the Lockheeds were used on front wheels only). Chrysler stuck with these until the early 1960s.

In the late '40s there was the first and much-remembered flurry of interest in disc brakes. Crosley adopted a design based on the Goodyear aircraft disc brake for its "Hotshot" sports car and Chrysler tried the Lambert self-energizing disc brake for the luxury Imperials. This latter had two clutch-like disc facings that rubbed against a disc, with a ball-and-ramp arrangement to allow brake torque to give a self-servo effect. The whole thing was contained in a finned aluminum housing. Neither of these disc brake installations survived very long. The Crosley design was too subject to dirt and water and the Chrysler couldn't dissipate heat efficiently. The American auto industry wasn't ready for disc brakes. After these two installations faded out, nothing was heard, domestically, of discs again for 10 years, although disc brake development boomed in Europe.

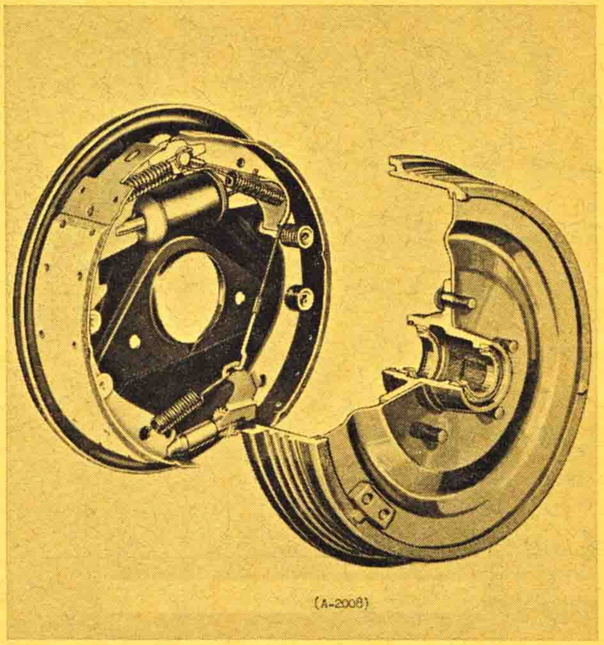
The American auto industry was very active in drum brake development during the 1950s. Vacuum power boosters reappeared in 1952 and have since become one of the most popular options on our cars. The Bendix duo-servo brake today has taken over completely, but vastly improved lining materials have made it acceptably stable. In 1956 Chrysler introduced its "center-plane" brake—where the shoe webbing was placed in the center of the lining (laterally), instead of on one edge. This minimized shoe distortion and gave more even contact around the drum. This brake was used with both single cylinder and 2-leading-shoe layout. During these years, carmakers were continually increasing the lining area by using greater drum diameter and width. This increased area not only increased heat capacity, but lengthened lining life to the 40,000 and 50,000-mile range. This was double the average lining life of 1930. Bonding the lining to the shoe, with heat and pressure and adhesive, gave a little increase in effective area by filling in the holes previously occupied by rivets.

In 1956 Chevrolet introduced ceramic-metallic linings for its racing Corvettes. Metallic lining had been used for years on some heavy-duty commercial vehicles (and was even quite widely used in Europe for cars before 1920), but the Chevrolet introduction got American auto engineers to thinking about the possibilities of metallic materials for heavy-duty car applications. This thinking eventually evolved to a base material of sintered iron, rather than the harsh ceramic material, and today optional metallic brakes can be ordered on a number of high-performance cars.

In 1958 Buick rocked the car world by going to aluminum front drums with bonded-in iron liners for volume-produced cars. This raised a lot of eyebrows because of the added cost.



SELF-ADJUSTMENT system used on virtually all U.S. cars has simple actuator which catches teeth on the adjusting screw star wheel when the car is backed. Wear allows actuator movement.

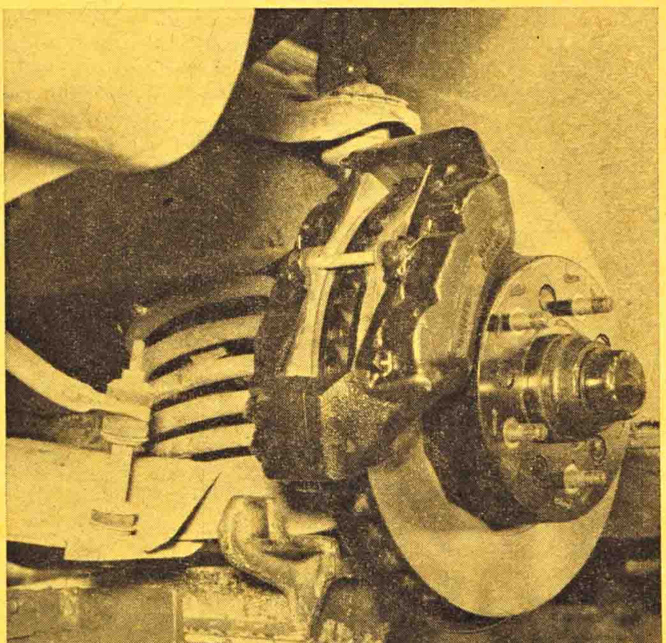


MODERN DRUM brakes feature large linings, ribbed and reinforced drums for minimum heat distortion. Hydraulic wheel cylinder is at top, self-adjustment mechanism at the bottom.

However, they're still being used and Buick has some of the best brakes in the industry. The high heat-dissipating ability of aluminum effectively controls lining fade under all but the toughest conditions. A number of other makers have finned their cast-iron drums for better heat dissipation. Another, but more obscure, trend is the attempt to improve the rigidity of brake drums by careful design of flanges and ribbing. Drum distortion under heat expansion is a big factor in brake fade. Modern brake drums are 10 times stiffer than those of a few years ago.

Of course the big brake news today is the disc brake. The disc brakes are much superior to almost any drum combination, unlike the premature designs of 1949, and it is likely they will be available on every sports-oriented car out of Detroit within two years. ■

DISC BRAKES on Corvette herald future for U.S. cars. Disc offers better heat rejection, less fade, lighter weight.



DRUM BRAKES' effectiveness have been improved with finned drums, which both reduce distortion and help cooling.